RESEARCH HIGHLIGHT

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MEASURING THE EFFORT NEEDED TO CLIMB ACCESS RAMPS IN A MANUAL WHEELCHAIR

INTRODUCTION

Obstacles that make it difficult or impossible for people with disabilities to enter or leave public areas, public buildings and private residences are often causes of social isolation. Over the past 15 years, social policies have attempted to minimize these obstacles.

Ramps are the usual choice to make buildings accessible to people who use wheelchairs. A variety of standards exist for the slope of wheelchair access ramps.[1] The most frequently suggested standard for both personal and universal accessibility is a slope of 1 in 12;[2] that is, a ramp that rises one unit for every 12 units in length.

CMHC recommends a standard of 1 in 20 for people 65 years of age or older and suggests that slopes steeper than 1 in 12 should be avoided.[3] The National Building Code of Canada[4] generally recommends the 1 in 20 slope since it is "safer and less strenuous." The Code notes that even a slope of 1 in 16 can be difficult or even dangerous for some people with reduced mobility, particularly during the winter.

The government of Quebec accepts a slope of 1 in 8.[5] CMHC also accepts a slope of 1 in 8 for internal ramps that are 2.5 metres long when it is absolutely impossible to do otherwise.[6] Martel and De Sart say that a 1 in 8 slope is only for ramps for motorized wheelchairs.[7]

Kushner, Falta & Aitkens say that the most frequently used standard is 1 in 12, but for short distances, they support slopes of 1 in 10 and 1 in 8.[8]

To construct ramps with the gentler slopes in existing buildings can be problematic at times because of lack of space. At the same time, there is not much literature scientifically demonstrating the different physical efforts required by slopes of 1 in 10, 1 in 12 and 1 in 20. Furthermore, most of the few studies that have been conducted are limited because they examined mainly men who were paraplegic as the result of a spinal cord injury and in excellent physical shape.[9]

The main goal of this research was to measure the physical effort needed by people who do not normally use a wheelchair to climb, in a manual wheelchair, each of the three most common slopes — 1 in 10, a less-steep slope of 1 in 12, and an even gentler slope of 1 in 20.

The research was conducted at the Natural Sciences and Engineering Research Council (NSERC) in the laboratory of the Industrial Research Chair on Wheelchair Seating Aids, in the Pavillon Jean-Brillant of the École Polytechnique de Montréal.

METHODOLOGY

The researchers calculated the mechanical efficiency needed by study participants to climb each slope in a wheelchair. This was measured by muscle-strength ratios—the push force used when climbing the slope, divided by the maximum push force the study participants could produce.

There were two research hypotheses:

1. physical requirements vary according to the slope, and
2. the ability to propel a wheelchair varies with age.

SUBJECT SELECTION

The subjects selected for the research were 39 men and women who did not normally use wheelchairs, ranging in age from 18 to 64. Two age groups were studied—18 to 39 and 40 to 64.

EXPERIMENT

There were four phases to the research. In the first phase, the researchers measured each subject's maximum isometric force in static situations, i.e., the maximum force used by the subjects to roll a manual wheelchair on the spot (the wheelchair's rear wheels

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rested on a roller). In the next three phases, the researchers assessed mechanical efficiency of manual propulsion, over short periods, for each of the three slopes.

The test subjects used a manual wheelchair with standard back and seat.[10] The wheelchair propulsion rail was replaced by a rail with instruments that measured the force exerted, using the SmartWheel.[11]

The wheelchair's rear wheels rested on a roller. The front wheels were fixed to a platform that could be tilted to simulate the three slopes.

Photo 1: Experimental wheelchair set-up

PROCEDURE

A doctoral student in biomedical engineering was responsible for operating the equipment and taking the measurements. An undergraduate student in occupational therapy recruited the participants and carried out the experiment with them.

The experiment included anthropometric and grip strength measurements; a static study, in which participants sat in the wheelchair and the isometric forces were measured using two hand angles, zero and 30 degrees; and, a dynamic study, in which participants sat in the wheelchairs and climbed a 10-metre ramp three times, once for each slope. There was a five-minute rest between each trial. The total experiment lasted 90 minutes for each participant.

Data analysis and processing

The statistical data analysis was conducted using an analysis of variance (ANOVA)[12] of two factors (age and ramp slope), and statistical software.[13] The voluntary isometric force (highest force exerted by the subject on the propulsion rail) was measured using the SmartWheel (static study). For the dynamic study, the total force measured was that resulting from the tangential, radial and axial forces. The highest total force for each cycle was retained. The researchers calculated the average of these total forces. The tangential force and the total force were calculated the same way.

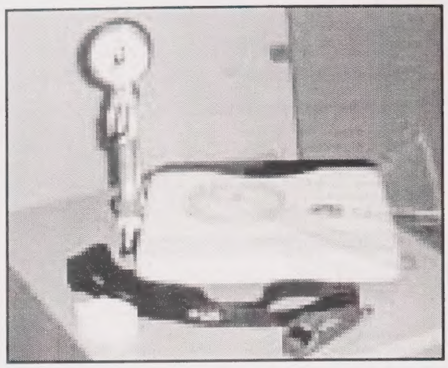

Photo 2: Device used to take anthropometric measurements.

FINDINGS

This study showed that mechanical efficiency varies significantly when an individual in a manual wheelchair climbs a 1 in 20 slope as compared to the 1 in 12 and 1 in 10 slopes.[14] The 1 in 20 ramp is easiest to climb, compared to the 1 in 12 and 1 in 10 slopes.

Based on current literature,[15] participants' subjective comments during the experiment, and on the day-to-day observations of people who use wheelchairs, the researchers expected to find a significant difference between the 1 in 12 and 1 in 10 slopes. As noted by Sanford,[16] not only is a slope of 1 in 10 considered much too difficult to climb, but a slope of 1 in 12 is starting to be perceived as too steep.

However, in this research there was no significant difference in physical effort between the 1 in 12 and 1 in 10 slopes. Mechanical efficiency was similar for both.

Observations from this study show that age does not seem to affect the ability to climb the 1 in 10, 1 in 12 and 1 in 20 slopes, at least between the two groups examined of 18–39 years and 40–64 years.[17]

In light of the results of this study, individuals, such as occupational therapists, building construction professionals, such as architects, and decision-makers, such as lawmakers, should consider ramps with a 1 in 20 slope. The 1 in 20 slope is less physically demanding and can serve a wider range of wheelchair users.

Although, subjectively, wheelchair users and participants in this research indicated that the 1 in 10 slope requires a greater effort than the 1 in 12 slope, the results of this research did not demonstrate any significant differences.

Lack of space for building access ramps with a 1 in 20 slope in existing buildings can be a major limitation. The 1 in 10 slope is economically advantageous because it makes a shorter ramp, can be built in less space and therefore is cheaper.

Photo 3: Experimental set-up for the static study.

One empirically observed factor must be considered for high-slope ramps: the risk of tipping over backwards. The Sanford[18] study raised this issue. It indicated that wheelchair users were worried when they faced ramps that were too steep. This factor should therefore be considered when designing access ramps.

This study did not consider climatic factors such as wind, ice, snow and rain, which may influence the effort and safety involved in climbing, and even more in descending, an access ramp. Additional research dealing with climatic factors and the physical effort and risks of descending access ramps is worthy of further exploration.

CONCLUSION

The results of this study offer an initial reflection regarding the application of currently recommended slope standards for access ramps. Based on the scientific data presented, the 1 in 20 slope makes access ramps much easier to use. If a 1 in 20 slope is not possible in existing buildings because of lack of space, the 1 in 10 slope is an alternative to the 1 in 12 slope because it needs less space than the 1 in 12 slope and does not seem to be more physically demanding.

Additional studies involving the 65+ population, people who use wheelchairs, and to explore the risks of tipping when descending access ramps in manual wheelchairs need to be conducted.

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[10] A Prima manual wheelchair made by Orthofab Inc. of Québec.

[11] The SmartWheel is a rim on a three-beam, strain gauge system with the beams positioned at 120 degrees. The strain gauge enabled the researchers to calculate the resultant force, and the three axial, radial and tangential components of the force. Asato, K. T., Cooper, R. A., Robertson, R.N., and Ster, J. F. (1993). SMARTWheels: Development and Testing of a System for Measuring Manual Wheelchair Propulsion Dynamics. IEEE Transactions on biomedical engineering, 40, (12), 1320-1324.

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[16] Sanford et al. (1997).

[17] $F=1.40$, degrees of freedom=1, 37, $p=0.2446$.

[18] Sanford et al. (1997).

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